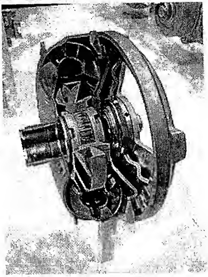
APPENDIX A

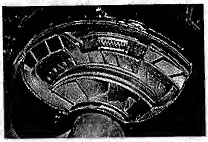
Document 1

Drehmomentwandler

aus Wikipedia, der freien Enzyklopädie



ZF Drehmomentwandler auf der BAUMA 2007



Drehmomentwandler (Schnittmodell) Porsche-Museum Stuttgart

Ein **Wandler**, auch **Drehmomentwandler** oder **Föttinger-Wandler** genannt, ist ein hydraulisches Bauelement, das eine Kraftübertragung zwischen Bauteilen, die mit unterschiedlichen Drehzahlen rotieren, ermöglicht. Drehmomentwandler gehören nicht zu den physikalischen Wandlern, sondern zu den variablen Getrieben, da sie eine Untersetzung bewirken. Sie werden als hydrodynamische Getriebe in Kraftfahrzeugen und Lokomotiven eingesetzt, ursprünglich wurden sie für Schiffsantriebe entwickelt. Als Erfinder gilt der Ingenieur Hermann Föttinger.

In Kraftfahrzeugen mit Automatikgetriebe wird heute meist ein **Trilok-Wandler** als Anfahrelement eingesetzt. Der Effekt des Trilok-Wandlers ist, dass beim Anfahren eine hohe Antriebsdrehzahl mit relativ geringem Drehmoment am Antrieb – bei geringer oder gar keiner Drehzahl am Abtrieb – ein hohes Drehmoment am Abtrieb erzeugt. Der Wechsel von hohem Drehmoment bei niedriger Abtriebsdrehzahl zu niedrigem Drehmoment bei hoher Abtriebsdrehzahl erfolgt stufenlos und selbsttätig bei konstanter Motorleistung. Der Wandlungsbereich liegt heute bei bis zu 1:3, das Abgangsdrehmoment erreicht das dreifache Eingangsdrehmoment.

Inhaltsverzeichnis

Funktionsweise

Das Prinzip der hydrodynamischen Kraftübertragung ist, dass eine Flüssigkeit (Öl, Wasser od. A.) von den Schaufeln des Pumpenrades erfasst und beschleunigt wird. Das Pumpenrad, das direkt von der Kurbelwelle angetrieben wird, wandelt die mechanische Energie des Motors in Strömungsenergie um (Wandler). Das Turbinenrad ist mit der Getriebeeingangswelle (des nachgeschalteten Automatikgetriebes, also der Ausgangswelle des Wandlers) verbunden.

Beim Anfahren dreht sich das Pumpenrad mit Motordrehzahl, das Turbinenrad und das Leitrad stehen still. Das Öl strömt vom Pumpenrad zum Turbinenrad, gibt seine Energie an dieses ab und

wird dabei umgelenkt. Das Turbinenrad beginnt sich zu drehen, wenn das Drehmoment am Turbinenrad größer ist als das Widerstandsmoment an der Getriebeantriebswelle. Der nun vom Turbinenrad ausgehende Ölstrom trifft auf die Schaufeln des Leitrads und versucht, diese entgegen der Drehrichtung von Pumpenrad und Turbinenrad zu drehen. Diese Drehrichtung ist durch den Freilauf blockiert. Das Öl stützt sich an den um etwa 90 Grad gekrümmten Schaufeln des Leitrades ab und bewirkt dabei einen starken Rückstau, der an den Schaufeln des Turbinenrades eine Vergrößerung der Drehkraft zur Folge hat. Durch die Erhöhung der Drehkraft ist das Drehmoment an der Turbinenradwelle (Getriebeantriebswelle) größer als das in den Drehmomentwandler eingeleitete Motordrehmoment. Das Leitrad leitet den Ölstrom in einem günstigen Winkel auf die Schaufeln des Pumpenrades. Damit ist der Ölkreislauf in sich geschlossen.

Soweit entspricht die Funktion der einer Föttinger-Kupplung.

Bei einem Wandler befindet sich zwischen Pumpen- und Turbinenrad ein zusätzliches Leitrad, das die Aufgabe hat, die aus dem Turbinenrad strömende Flüssigkeit so umzulenken, dass sie mit optimaler Anströmrichtung wieder dem Pumpenrad zugeleitet wird. Durch diese Umlenkung erhöht sich das Moment am Turbinenrad. Gleichzeitig erfährt auch das Reaktionsglied (Leitrad) ein entsprechendes Moment, das abgestützt werden muss. Das Leitrad ist als Momentenstütze notwendig, da andernfalls keine Drehmomentwandlung erfolgen kann und nur die Funktion einer reinen Kupplung erreicht würde. Die übertragene Leistung steigt mit der Drehzahl an.

Die Drehmomentüberhöhung hängt auch von der Drehzahldifferenz zwischen Pumpen- und Turbinenrad ab. Je größer die Differenz, umso größer kann auch die Drehmomentüberhöhung werden. Wenn sich beide Drehzahlen angleichen, sinkt der Wirkungsgrad und die Momentenüberhöhung des Wandlers ab. Aus diesem Grund lagert man beim Trilok-Wandler das Leitrad auf einem Freilauf, sodass unter bestimmten Strömungsverhältnissen der Wandler wieder zur reinen hydrodynamischen Kupplung (*Kupplungsbereich*) wird und das Leitrad frei mitdreht. Sobald das Pumpenrad und das Turbinenrad beinahe die gleiche Drehzahl haben, sinkt der Wirkungsgrad des Wandlers. Aus diesem Grund wird bei neueren Automatikgetrieben eine Überbrückungskupplung (Wandlerüberbrückungskupplung, kurz: WÜK) geschlossen. Diese verbindet das Pumpenradgehäuse mit dem Turbinenrad. Somit hat der Drehmomentwandler einen Wirkungsgrad von 100%, jedoch wird das Drehmoment nicht mehr verstärkt.

Beim Föttinger-Wandler kommt es auf Grund der fehlenden Drehmomentwandlung bei großen Drehzahldifferenzen zwischen An- und Abtrieb zu einer starken Wirkungsgradabsenkung.

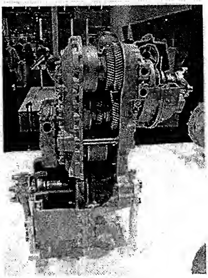
Der Wandler dämpft auch Drehschwingungen im Antriebsstrang, so dass Anregungen des Motors nicht über die Kardan- und Antriebswellen auf die Karosserie zurückübertragen werden.

Einbau in Fahrzeugen

Der Drehmomentwandler wird typischerweise in Automatikgetrieben eingesetzt und verbindet die Kurbelwelle mit dem Getriebe.

Dass der Wirkungsgrad des Trilok-Wandlers im Wandlungsbereich selten 85 % übersteigt und im Kupplungsbereich bei etwa 95 % liegt, führt dazu, dass ein erheblicher Teil der Getriebe-Eingangsleistung in Wärme umgesetzt wird, die abgeführt werden muss. Darum wird ein Teil der Flüssigkeit permanent in Umlauf gehalten und gekühlt. Um den Leistungsverlust möglichst gering zu halten, kommt bei modernen PKW eine Überbrückungskupplung zum Einsatz. Die Kupplung verbindet Ein- und Ausgangswelle und überbrückt damit den Drehmomentwandler. Häufig wird die Kupplung schon in den niedrigen Gängen verwendet und der Drehmomentwandler weitgehend auf

seine Funktion als Anfahrelement beschränkt. Beim Anfahren bietet ein Trilok-Wandler dank Momentenüberhöhung sogar einen höheren Wirkungsgrad als eine schleifende konventionelle Kupplung. Autos mit ideal ausgelegten Getriebeautomaten und Drehmomentwandlern können dank der Drehmomentüberhöhung des Trilok-Wandlers oft schneller beschleunigen als gleiche handgeschaltete Fahrzeuge.


Drehmomentwandler (rechts oben) in einem Baumaschinengetriebe

Mit der Überbrückung des Drehmomentwandlers verbessert sich der Wirkungsgrad, aber damit wird auch der schwingungsdämpfende Effekt eliminiert, da die Kraftübertragung über mechanischen Kraftschluss und nicht mehr über die Hydraulikflüssigkeit stattfindet. Um hier den Komfortanforderungen gerecht zu werden, können sogenannte Turbinentorsionsdämpfer (TTD) eingesetzt werden. Eine weitere Möglichkeit, diesen Nachteil zu minimieren, besteht darin, die Wandlerüberbrückungskupplung nicht vollständig zu schließen, sondern mit einer last- und drehzahlabhängigen Schlupfdrehzahl zu betreiben. Die hierbei in den Reibelementen der Überbrückungskupplung entstehende Wärme muss allerdings ebenfalls über einen ausreichend dimensionierten, kontinuierlichen Austausch der Flüssigkeit im Wandler abgeführt werden.

Siehe auch

- Strömungsgetriebe
- Visco-Kupplung

Literatur

- Hans Joachim Förster: Stufenlose Fahrzeuggetriebe in mechanischer, hydrostatischer, hydrodynamischer, elektrischer Bauart und in Leistungsverzweigung : Grundlagen, Bauformen, Wechselwirkung, ISBN 3-8249-0268-0, Verlag TÜV Rheinland

Weblinks

Commons: Drehmomentwandler (http://commons.wikimedia.org/wiki/Category:Torque_converters?uselang=de) – Sammlung von Bildern, Videos und Audiodateien

- LUK hydraulischer Drehmomentwandler (http://luktest1.ina.com/content.luk.de/de/products/transmission_components/automatic_transm

Von „http://de.wikipedia.org/wiki/Drehmomentwandler“
Kategorien: Fluidelement | Hydromechanik

- Datenschutz
- Über Wikipedia
- Impressum

United States Patent [19]

Boss et al.

[11] **4,362,017**

[45] **Dec. 7, 1982**

[54] **HYDRAULIC TORQUE CONVERTER**

[75] Inventors: **Franz Boss**, Kressbronn; **Gerold Bieber**, Langenargen; **Karlheinz Schachmann**, Friedrichshafen, all of Fed. Rep. of Germany

[73] Assignee: **Zahnradfabrik Friedrichshafen AG**, Friedrichshafen, Fed. Rep. of Germany

[21] Appl. No.: **128,081**

[22] Filed: **Mar. 7, 1980**

[30] **Foreign Application Priority Data**

Mar. 14, 1979 [DE] Fed. Rep. of Germany 2909968

[51] Int. Cl.³ **F16H 41/30**

[52] U.S. Cl. **60/337**; 60/330; 60/361

[58] Field of Search 60/337, 339, 358, 367, 60/362, 329, 330, 345, 361

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,679,728	6/1954	Trail	60/337
2,818,708	1/1958	Kelley	60/337
2,994,197	8/1961	Mamo	60/362 X
3,125,857	3/1964	Schneider	60/361
3,507,118	4/1970	Yamaguchi et al.	60/345
3,724,209	4/1973	Fackenthal	60/357
3,785,155	1/1974	Upton	60/352 X
3,841,094	10/1974	Cobb	60/363 X

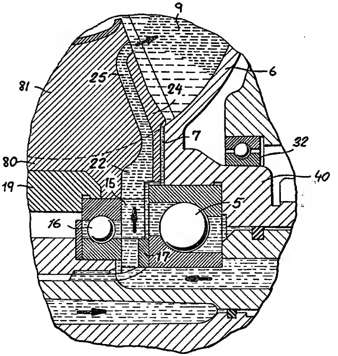
Primary Examiner—Gerald A. Michalsky

Attorney, Agent, or Firm—Karl F. Ross

[57] **ABSTRACT**

A hydraulic torque converter with a toroidal space bounded by a pump member, a turbine member and a free-wheeling stator has an inlet channel for fresh transmission fluid (oil) which opens into the pump torus at a location spaced from the pump member, preferably via the stator, whereby the relatively cool volume of newly admitted fluid mingles with the fluid already present instead of being immediately centrifugated toward the peripheries of the pump and turbine members from which it would quickly return to the sump. The inlet channel may include one or more radial passages in a spacer ring separating the stationary races of the journal bearings by which the pump member and the stator are supported on a trunnion rigid with the converter housing.

3 Claims, 4 Drawing Figures



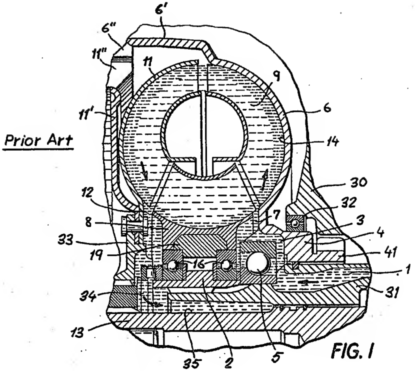

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FIG. 1

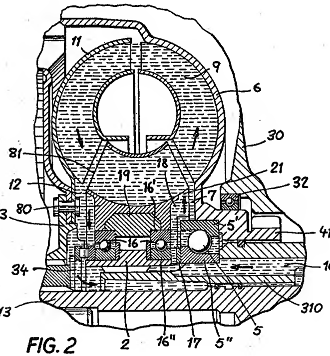
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FIG. 2

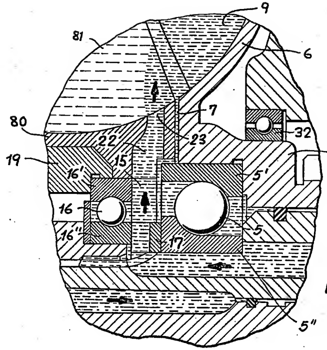
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FIG. 3

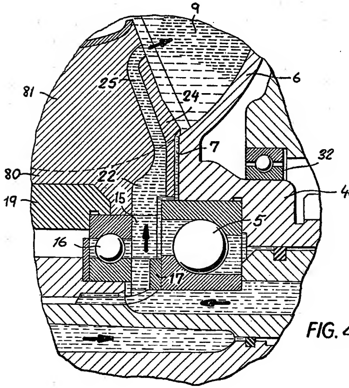
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FIG. 4

HYDRAULIC TORQUE CONVERTER

FIELD OF THE INVENTION

Our present invention relates to a hydraulic torque converter as used, for example, in an automotive transmission.

BACKGROUND OF THE INVENTION

Torque converters generally comprise an externally powered driving member, known as a pump, and a driven member, known as a turbine, each having the shape of a torus. The two members are coaxially mounted in a housing for independent rotation and have blade-supporting peripheral walls jointly defining a toroidal space filled with transmission fluid hereinafter referred to as oil. This toroidal space is also bounded, along a peripheral zone closest to the axis of rotation, by blade-supporting walls of a so-called stator which, however, generally is not stationary but is free-wheeling in the housing to serve as a return guide for the oil circulating within that space between the blades of all three members. In the system here contemplated, some of the oil is continuously drained off to a sump and, after cooling in an external circuit, is returned to the converter by a supply pump. Certain converters operating according to this principle are known under the designation Trilok.

Conventionally, the fresh oil is admitted into the toroidal converter space through an inlet which terminates in a channel passing through the hub of the pump member and opens into the torus thereof while the spent oil is removed from the torus of the turbine member through an outlet partly passing through the hub of the latter. Though this arrangement has certain structural conveniences, it sets the relatively cold incoming oil in immediate rotation at substantially the speed of the pump member and centrifugates it, on account of its greater specific gravity, toward the periphery of the toroidal converter space whence most of it promptly flows to the outlet and thus to the sump. The externally cooled oil, therefore, mingles only to a minor extent with the hotter oil circulating in the converter space whereby the heat generated in the converter, which may be particularly intense with repeated starts and stops of a vehicle using same, is dissipated only at a slow rate. It thus often becomes necessary, in order to prevent overheating, to use outsize supply pumps and coolers for the recirculation of a sufficient amount of oil.

OBJECT OF THE INVENTION

The object of our present invention, therefore, is to provide means in such a converter for improving the cooling effect of the externally recirculated oil, thereby allowing a reduction in the sizes of the supply pump and the cooler included in the external circuit.

SUMMARY OF THE INVENTION

In accordance with our present improvement, the inlet for fresh oil coming from the supply pump no longer passes through the hub of the pump member but terminates in a channel which opens into a toroidal converter space at a location spaced from that member.

Advantageously, the channel for the incoming oil passes through the body of the stator which is generally the slowest-moving member of the converter. In principle, however, we could also let the incoming oil enter the converter space through the turbine member which at times of large heat generation rotates considerably more slowly than the pump member.

The greater thermal efficiency realized with our invention, aside from enabling the use of smaller supply pumps and oil coolers, may also allow a reduction in the overall dimensions of the converter itself since less consideration need be given to the ability of its pump and turbine members to dissipate some of the heat by radiation to the outside. This, in turn, enables greater compactness of the entire transmission whose mechanical parts generally have a diameter substantially less than that of the converter. With less oil subjected to forced recirculation by an external supply pump, the system operates at higher overall efficiency.

BRIEF DESCRIPTION OF THE DRAWING

Our invention will now be described in detail with reference to the accompanying drawing in which:

FIG. 1 is a cross-sectional view of the upper half of a conventional hydraulic torque converter to which our invention is applicable;

FIG. 2 is a view similar to FIG. 1 but illustrating our present improvement; and

FIGS. 3 and 4 are two fragmentary sectional views drawn to a larger scale and showing certain modifications of the embodiment illustrated in FIG. 2.

SPECIFIC DESCRIPTION

In FIG. 1 we have shown a conventional Trilok-type converter with a housing 30 forming a stationary trunnion 31 in which an output shaft 13 is rotatably journaled. Trunnion 31 supports, via a ball bearing 5, a hub 4 of a pump member 6 to which rotation is imparted via a pinion 41 forming part of an otherwise nonillustrated gear train powered by the engine of an automotive vehicle. Hub 4 is further braced against housing 30 by a counterbearing 32.

A stationary sleeve 2 splined onto trunnion 31 supports, via ball bearings 16, a hub 19 of a stator 8 lying between pump member 6 and a turbine member 11. The latter has a hub 33 by which it is mounted on output shaft 13 and which is separated by a gap 12 from the body of stator 8. An inlet 1 in trunnion 31 serves for the admission of fresh, cool oil from an external supply pump, not shown, this inlet communicating with radial passages 3 in hub 4 through which the incoming oil enters a gap 7 between stator 8 and pump member 6. The incoming oil, already set in rotation at substantially the speed of pump member 6 upon flowing through passages 3, hardly mixes with the oil circulating in a toroidal space 9 defined by members 6, 8 and 11 but is centrifugally accelerated, owing to its higher specific gravity, along the peripheral surface 14 of pump member 6 and continues between the blades thereof until it reaches the blades of turbine member 11 in the other half of space 9. Hugging the peripheral wall of the turbine member, most of this cooler oil then enters the gap 12 and exits from the converter via a passage 34 in turbine hub 33 from which an annular clearance 35 between shaft 13 and trunnion 31 leads to a nonillustrated sump. FIG. 1 also shows extensions 6' and 11' of pump and turbine members 6 and 11 carrying cooling fins 6" and 11".

In FIG. 2 (see also FIGS. 3 and 4) we have illustrated an improved converter according to our present invention whose housing 30, pump number 6, turbine member 11 and output shaft 13 are substantially identical with

those of FIG. 1. The pump member 6 is here provided with a hub 40 resting solidly against the outer race 5' of bearing 5 while lacking the passages 3 of the hub 4 shown in FIG. 1. A trunnion 310, rigid with housing 30, has an extended inlet 10 which passes inside the inner race 5" of bearing 5 and terminates at a spacer ring 17 inserted between this race 5" and the corresponding inner race 16" of the adjoining stator bearing 16 whose outer race 16' is separated from outer race 5' by an annular space 15 forming an extension of gap 7. Ring 17 has at least one radial passage through which the incoming oil enters the space 15 as more clearly shown in FIGS. 3 and 4. The body of a stator 80, mounted on hub 19 and carrying blades 81, is formed with one or more radial channels 18 terminating in one or more nozzles 21 through which the incoming oil is admitted into the gap 7 between pump member 6 and stator 80 at locations just ahead of blades 81.

Since the oil entering the toroidal converter space 9 is subjected to little or no peripheral acceleration, it readily mixes with the fluid already circulating in that space and effectively cools it. The outgoing flow by way of gap 12 and channel 34, accordingly, consists to a significant extent of oil which has circulated for a considerable time in space 9 and has therefore a substantially higher temperature than the incoming oil.

The oil entering the annular space 15 also spreads out into ball bearings 5 and 16 to help lubricate same. In FIGS. 3 and 4 we have shown this space 15 to open directly into the gap 7 so that part of the entering oil also comes into contact with the rotating outer race 5' supporting the pump hub 40. Except for a small layer of oil flowing through the gap 7, however, the incoming flow passes in FIG. 3 through one or more channels 22 of stator body 80 which terminate at respective ports 23 near the roots of blades 81. In FIG. 4 an extension 25 of channel 22 passes through part of a blade 81 so as to open into space 9 at a point still farther away from pump member 6. In the latter instance, the oil flow through the gap 7 is further throttled by an overhanging bulge 24 of the stator body.

We claim:

1. In a hydraulic torque converter wherein a pump member, a turbine member and a stator member have coaxial hubs independently rotatable inside a housing and have blade-supporting peripheral walls defining a toroidal space filled with transmission fluid, said stator member and said pump member being separated from each other by a gap, the hub of said turbine member being mounted on an output shaft journaled in a trunnion of said housing, said trunnion forming an inlet for fresh fluid and an outlet for spent fluid, the hubs of said pump member and of said stator member being respectively supported on said trunnion by first and second bearing means axially spaced from each other,

the improvement wherein said inlet passes inwardly of said first bearing means and terminates at a passage which extends between said first and second bearing means and communicates with at least one generally radial channel in the body of said stator member which passes through a blade of said stator member and opens into said toroidal space at a location radially outward from the hub of said pump member, said passage also communicating with said gap for letting a minor portion of the incoming fluid enter said toroidal space outside said channel.

2. A torque converter as defined in claim 1 wherein said passage is formed in a spacer ring separating said first and second bearing means from each other.

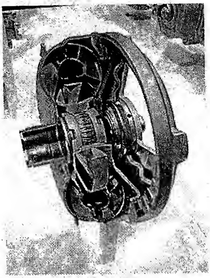
3. The torque converter defined in claims 1 or 2 wherein an extension of said outlet lies between said stator member and the hub of said turbine member.

* * * * *

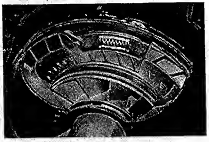
Document 2

Torque converter

From Wikipedia, the free encyclopedia



ZF torque converter cut-away



A cut-away model of a torque converter

A **torque converter** is a fluid coupling that is used to transfer rotating power from a prime mover, such as an internal combustion engine or electric motor, to a rotating driven load. Like a basic fluid coupling, the torque converter normally takes the place of a mechanical clutch, allowing the load to be separated from the power source. As a more advanced form of fluid coupling, however, a torque converter is able to multiply torque when there is a substantial difference between input and output rotational speed, thus providing the equivalent of a reduction gear.

Contents

Usage

- Automatic transmissions on automobiles, such as cars, buses, and on/off highway trucks.
- Forwarders and other heavy duty vehicles.
- Marine propulsion systems.
- Industrial power transmission such as conveyor drives, almost all modern forklifts, winches, drilling rigs, construction equipment, and locomotives.

Function

Torque converter elements

A fluid coupling is a two element drive that is incapable of multiplying torque, while a torque converter has at least one extra element—the stator—which alters the drive's characteristics during periods of high slippage, producing an increase in output torque.

In a torque converter there are at least three rotating elements: the pump, which is mechanically driven by the prime mover; the turbine, which drives the load; and the stator, which is interposed between the pump and turbine so that it can alter oil flow returning from the turbine to the pump. The classic torque converter design dictates that the stator be prevented from rotating under any condition, hence the term *stator*. In practice, however, the stator is mounted on an overrunning clutch, which prevents the stator from counter-rotating with respect to the prime mover but allows forward rotation.

Modifications to the basic three element design have been periodically incorporated, especially in applications where higher than normal torque multiplication is required. Most commonly, these have taken the form of multiple turbines and stators, each set being designed to produce differing amounts of torque multiplication. For example, the Buick Dynaflow automatic transmission was a non-shifting design and, under normal conditions, relied solely upon the converter to multiply torque. The Dynaflow used a five element converter to produce the wide range of torque multiplication needed to propel a heavy vehicle.

Although not strictly a part of classic torque converter design, many automotive converters include a lock-up clutch to improve cruising power transmission efficiency and reduce heat. The application of the clutch locks the turbine to the pump, causing all power transmission to be mechanical, thus eliminating losses associated with fluid drive.

Operational phases

A torque converter has three stages of operation:

- **Stall.** The prime mover is applying power to the pump but the turbine cannot rotate. For example, in an automobile, this stage of operation would occur when the driver has placed the transmission in gear but is preventing the vehicle from moving by continuing to apply the brakes. At stall, the torque converter can produce maximum torque multiplication if sufficient input power is applied (the resulting multiplication is called the *stall ratio*). The stall phase actually lasts for a brief period when the load (e.g., vehicle) initially starts to move, as there will be a very large difference between pump and turbine speed.

- **Acceleration.** The load is accelerating but there still is a relatively large difference between pump and turbine speed. Under this condition, the converter will produce torque multiplication that is less than what could be achieved under stall conditions. The amount of multiplication will depend upon the actual difference between pump and turbine speed, as well as various other design factors.

- **Coupling.** The turbine has reached approximately 90 percent of the speed of the pump. Torque multiplication has essentially ceased and the torque converter is behaving in a manner similar to a plain fluid coupling. In modern automotive applications, it is usually at this stage of operation where the lock-up clutch is applied, a procedure that tends to improve fuel efficiency.

The key to the torque converter's ability to multiply torque lies in the stator. In the classic fluid coupling design, periods of high slippage cause the fluid flow returning from the turbine to the pump to oppose the direction of pump rotation, leading to a significant loss of efficiency and the generation of considerable waste heat. Under the same condition in a torque converter, the returning fluid will be redirected by the stator so that it aids the rotation of the pump, instead of impeding it. The result is that much of the energy in the returning fluid is recovered and added to the energy being applied to the pump by the prime mover. This action causes a substantial increase in the mass of fluid being directed to the turbine, producing an increase in output torque. Since the returning fluid is initially traveling in a direction opposite to pump rotation, the stator will likewise attempt to counter-rotate as it forces the fluid to change direction, an effect that is prevented by the one-way stator clutch.

Unlike the radially straight blades used in a plain fluid coupling, a torque converter's turbine and stator use angled and curved blades. The blade shape of the stator is what alters the path of the fluid, forcing it to coincide with the pump rotation. The matching curve of the turbine blades helps to correctly direct the returning fluid to the stator so the latter can do its job. The shape of the blades is important as minor variations can result in significant changes to the converter's performance.

During the stall and acceleration phases, in which torque multiplication occurs, the stator remains stationary due to the action of its one-way clutch. However, as the torque converter approaches the coupling phase, the energy and volume of the fluid returning from the turbine will gradually decrease, causing pressure on the stator to likewise decrease. Once in the coupling phase, the returning fluid will reverse direction and now rotate in the direction of the pump and turbine, an effect which will attempt to forward-rotate the stator. At this point, the stator clutch will release and the pump, turbine and stator will all (more or less) turn as a unit.

Unavoidably, some of the fluid's kinetic energy will be lost due to friction and turbulence, causing the converter to generate waste heat (dissipated in many applications by water cooling). This effect, often referred to as pumping loss, will be most pronounced at or near stall conditions. In modern designs, the blade geometry minimizes oil velocity at low pump speeds, which allows the turbine to be stalled for long periods with little danger of overheating.

Efficiency and torque multiplication

A torque converter cannot achieve 100 percent coupling efficiency. The classic three element torque converter has an efficiency curve that resembles ∩: zero efficiency at stall, generally increasing efficiency during the acceleration phase and low efficiency in the coupling phase. The loss of efficiency as the converter enters the coupling phase is a result of the turbulence and fluid flow interference generated by the stator, and as previously mentioned, is commonly overcome by mounting the stator on a one-way clutch.

Even with the benefit of the one-way stator clutch, a converter cannot achieve the same level of efficiency in the coupling phase as an equivalently sized fluid coupling. Some loss is due to the presence of the stator (even though rotating as part of the assembly), as it always generates some power-absorbing turbulence. Most of the loss, however, is caused by the curved and angled turbine blades, which do not absorb kinetic energy from the fluid mass as well as radially straight blades. Since the turbine blade geometry is a crucial factor in the converter's ability to multiply torque, trade-offs between torque multiplication and coupling efficiency are inevitable. In automotive applications, where steady improvements in fuel economy have been mandated by market forces and government edict, the nearly universal use of a lock-up clutch has helped to eliminate the converter from the efficiency equation during cruising operation.

The maximum amount of torque multiplication produced by a converter is highly dependent on the size and geometry of the turbine and stator blades, and is generated only when the converter is at or near the stall phase of operation. Typical stall torque multiplication ratios range from 1.8:1 to 2.5:1 for most automotive applications (although multi-element designs as used in the Buick Dynaflow and Chevrolet Turboglide could produce more). Specialized converters designed for industrial or heavy marine power transmission systems are capable of as much as 5.0:1 multiplication. Generally speaking, there is a trade-off between maximum torque multiplication and efficiency—high stall ratio converters tend to be relatively inefficient below the coupling speed, whereas low stall ratio converters tend to provide less possible torque multiplication.

While torque multiplication increases the torque delivered to the turbine output shaft, it also increases the slippage within the converter, raising the temperature of the fluid and reducing overall efficiency. For this reason, the characteristics of the torque converter must be carefully matched to the torque curve of the power source and the intended application. Changing the blade geometry of the stator and/or turbine will change the torque-stall characteristics, as well as the overall efficiency

of the unit. For example, drag racing automatic transmissions often use converters modified to produce high stall speeds to improve off-the-line torque, and to get into the power band of the engine more quickly. Highway vehicles generally use lower stall torque converters to limit heat production, and provide a more firm feeling to the vehicle's characteristics.

A design feature once found in some General Motors automatic transmissions was the variable-pitch stator, in which the blades' angle of attack could be varied in response to changes in engine speed and load. The effect of this was to vary the amount of torque multiplication produced by the converter. At the normal angle of attack, the stator caused the converter to produce a moderate amount of multiplication but with a higher level of efficiency. If the driver abruptly opened the throttle, a valve would switch the stator pitch to a different angle of attack, increasing torque multiplication at the expense of efficiency.

Some torque converters use multiple stators and/or multiple turbines to provide a wider range of torque multiplication. Such multiple-element converters are more common in industrial environments than in automotive transmissions, but automotive applications such as Buick's Triple Turbine Dynaflow and Chevrolet's Turboglide also existed. The Buick Dynaflow utilized the torque-multiplying characteristics of its planetary gearset in conjunction with the torque converter for low gear and bypassed the first turbine, using only the second turbine as vehicle speed increased. The unavoidable trade-off with this arrangement was low efficiency and eventually these transmissions were discontinued in favor of the more efficient three speed units with a conventional three element torque converter.

Lock-up torque converters

As described above, pumping losses within the torque converter reduce efficiency and generate waste heat. In modern automotive applications, this problem is commonly avoided by use of a lock-up clutch that physically links the pump and turbine, effectively changing the converter into a purely mechanical coupling. The result is no slippage, and virtually no power loss.

The first automotive application of the lock-up principle was Packard's Ultramatic transmission, introduced in 1949, which locked up the converter at cruising speeds, unlocking when the throttle was floored for quick acceleration or as the vehicle slowed down. This feature was also present in some Borg-Warner transmissions produced during the 1950s. It fell out of favor in subsequent years due to its extra complexity and cost. In the late 1970s lock-up clutches started to reappear in response to demands for improved fuel economy, and are now nearly universal in automotive applications.

Capacity and failure modes

As with a basic fluid coupling the theoretical torque capacity of a converter is proportional to $r N^2 D^5$, where r is the mass density of the fluid, N is the impeller speed (rpm), and D is the diameter.[1] In practice, the maximum torque capacity is limited by the mechanical characteristics of the materials used in the converter's components, as well as the ability of the converter to dissipate heat (often through water cooling). As an aid to strength, reliability and economy of production, most automotive converter housings are of welded construction. Industrial units are usually assembled with bolted housings, a design feature that eases the process of inspection and repair, but adds to the cost of producing the converter.

In high performance, racing and heavy duty commercial converters, the pump and turbine may be further strengthened by a process called furnace brazing, in which molten brass is drawn into seams and joints to produce a stronger bond between the blades, hubs and annular ring(s). Because the furnace brazing process creates a small radius at the point where a blade meets with a hub or annular

ring, a theoretical decrease in turbulence will occur, resulting in a corresponding increase in efficiency.

Overloading a converter can result in several failure modes, some of them potentially dangerous in nature:

- **Overheating**: Continuous high levels of slippage may overwhelm the converter's ability to dissipate heat, resulting in damage to the elastomer seals that retain fluid inside the converter. This will cause the unit to leak and eventually stop functioning due to lack of fluid.

- **Stator clutch seizure**: The inner and outer elements of the one-way stator clutch become permanently locked together, thus preventing the stator from rotating during the coupling phase. Most often, seizure is precipitated by severe loading and subsequent distortion of the clutch components. Eventually, galling of the mating parts occurs, which triggers seizure. A converter with a seized stator clutch will exhibit very poor efficiency during the coupling phase, and in a motor vehicle, fuel consumption will drastically increase. Converter overheating under such conditions will usually occur if continued operation is attempted.

- **Stator clutch breakage**: A very abrupt application of power can cause shock loading to the stator clutch, resulting in breakage. When this occurs, the stator will freely counter-rotate the pump and almost no power transmission will take place. In an automobile, the effect is similar to a severe case of transmission slippage and the vehicle is all but incapable of moving under its own power.

- **Blade deformation and fragmentation**: Due to abrupt loading or excessive heating of the converter, the pump and/or turbine blades may be deformed, separated from their hubs and/or annular rings, or may break up into fragments. At the least, such a failure will result in a significant loss of efficiency, producing symptoms similar (although less pronounced) to those accompanying stator clutch failure. In extreme cases, catastrophic destruction of the converter will occur.

- **Ballooning**: Prolonged operation under excessive loading, very abrupt application of load, or operating a torque converter at very high RPM may cause the shape of the converter's housing to be physically distorted due to internal pressure and/or the stress imposed by centrifugal force. Under extreme conditions, ballooning will cause the converter housing to rupture, resulting in the violent dispersal of hot oil and metal fragments over a wide area.

Manufacturers

Current

- Allison Transmission, used in bus, refuse, fire, construction, distribution, military and specialty applications
- BorgWarner, used in automobiles
- Subaru, used in automobiles
- Twin Disc, used in vehicle, marine and oilfield applications
- Voith Turbo-Transmissions, used in many diesel locomotives and diesel multiple units
- ZF Friedrichshafen, used in automobiles

Past

- Lysholm-Smith, named after its inventor, Alf Lysholm, and used in some British Rail Derby Lightweight diesel multiple units
- Mekydro [2], used in British Rail Class 35 *Hymek* locomotives

- Packard, used in the Ultramatic automobile transmission system
- Rolls-Royce (Twin Disc), used in some British United Traction diesel multiple units

See also

- Fluid coupling
- Water brake
- Electrical brakes

References

1. ^ *Hydrodynamic couplings and converters*. Automotive Handbook (3rd ed.). Robert Bosch. pp. 539. ISBN 0-8376-0330-7.
2. ^ http://www.intertrains.co.uk/glossary/m/mekydro-transmission.html

External links

- HowStuffWorks (http://auto.howstuffworks.com/torque-converter.htm) article on torque converters
- Subaru (http://www.drive.subaru.com/Fall02_TorqueConvert.htm) article on Subaru torque converters

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